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ABSTRACT

This thesis describes the development of a new capacity planning methodology to aid computer professionals working on implementing a capacity planning effort in an MVS environment. The methodology developed utilizes the System Management Facility (SMF), the Resource Measurement Facility (RMF), and the Statistical Analysis System (SAS) in order to bring together many of the past computer performance evaluation ideas and to integrate them with current computer performance evaluation techniques and automated procedures. An automated approach is taken so computer professionals can devote their energies to analyzing and interpreting results, not gathering and calculating input factors. Subsequently, each MVS installation is supplied with the actual usage data to help set accurate user objectives and forecast for tomorrow's data processing needs.

AN INTRODUCTION TO IMPLEMENTING A CAPACITY PLANNING EFFORT IN AN MVS ENVIRONMENT

BY

PAUL JOHN WALDOWSKI, 1952-

A THESIS

Presented to the Faculty of the Graduate School of the

UNIVERSITY OF MISSOURI-ROLLA

In Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE IN COMPUTER SCIENCE

1987

Approved by

Billy E. Gillett (Advisor)

Dedicated to the memory of my grandmother,

PEARL WALDOWSKI KRUCK

and

To my wife,

PAULA

and children,

JOHN and ANDREW

[illegible]

ABSTRACT

This thesis describes the development of a new capacity planning methodology to aid computer professionals working on implementing a capacity planning effort in an MVS environment. The methodology developed utilizes the System Management Facility (SMF), the Resource Measurement Facility (RMF), and the Statistical Analysis System (SAS) in order to bring together many of the past computer performance evaluation ideas and to integrate them with current computer performance evaluation techniques and automated procedures. An automated approach is taken so computer professionals can devote their energies to analyzing and interpreting results, not gathering and calculating input factors. Subsequently, each MVS installation is supplied with the actual usage data to help set accurate user objectives and forecast for tomorrow's data processing needs. Keywords: [illegible] computer programs, [illegible] Systems approach [illegible]

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I am especially indebted to Gene Bloom, Major, United States Air Force (Retired), for providing the author with the freedom to research capacity planning at the TRICOMS system shop located at Offutt AFB, Nebraska during 1984-85. It was during this time that the author formulated the basic subject matter of this thesis.

Special recognition is given to fellow colleagues Del McClure, William Baken, and Grady Bishop for their technical advice, comments, and most valuable suggestions.

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I. INTRODUCTION

A. PROBLEM DEFINITION

In today's dynamic data processing environments, the most crucial problem facing the management of a computer center running IBM's Multiple Virtual Storage (MVS) operating system is that of identifying the point in time when the arrival rate of the work will exceed the capacity of the available resources to process it within the desired service objectives. The main obstacles to the solution of this problem include an overabundance of raw data that encumbers efficient measurement of the MVS system and the difficulty in selecting a modeling approach that can be used to draw quick and accurate conclusions about a computer system's capacity. The issue is further complicated by the disjoint measurement tools and management science techniques currently available for various computing workloads (i.e. batch, time sharing, transaction oriented).

B. PURPOSE AND SCOPE

The basic objective of this thesis is to outline those aspects of a new capacity planning methodology to the technical person who is highly skilled in MVS. This paper focuses on a measurement tool for data gathering, a software system for today's decision support and operation research needs, plus an overview of modeling approaches available to

address capacity planning. It presupposes some familiarity with the System Management Facility (SMF), the Resource Measurement Facility (RMF), and the Statistical Analysis System (SAS) upon which this methodology is based. Although the approach is general, the information provided is comprehensive enough to allow computer professionals at any MVS installation to participate in the various tasks which need to be accomplished to implement a capacity planning effort.

C. PROBLEM SIGNIFICANCE

The demand for a capacity planning methodology has long been a vital concern of many MVS installations. In the past, various methodologies have been developed and used with some degree of success. However, their use has been limited, primarily because of the difficulties in selecting a source of raw data which adequately describes the actual computing environment to be measured.

It was at Offutt AFB, Nebraska, as a systems programmer and later as a performance systems analyst where the author first realized the true significance of this problem. This experience, correlated with graduate studies in computer science, has led the author to venture into researching this problem. Other key factors which contributed to performing this in-depth study include the following:

1. Like most MVS installations, data gathering became a very time consuming endeavor. The performance systems

analysts were so busy coding and maintaining programs, along with fixing and debugging job streams which failed to run for some reason or another, that they did not have time to work on capacity planning issues.

2. Moreover, when data was gathered successfully , it was recycled every ten weeks. This meant no historical data was available to find out what happened three months ago, let alone project what might happen in the next three months.

3. Due to an unfortunate reporting structure at the installation where this study was started, reporting procedures failed to provide management with an efficient way of obtaining the information required to make knowledgeable acquisition decisions which will accomodate future growth. In addition, the hardware configurations were constantly being changed, which meant one had to rummage through tons of paper-work, hoping to find when the last change occurred. These led to many acquisition decisions which did not accomodate future growth, but fulfilled political expectations.

4. In many instances at this installation, valuable man hours were being wasted doing mundane tasks which should have been automated. Hence, many computer professionals were not gaining the necessary skills to do capacity planning.

The views expressed above and throughout this thesis are those of the author and do not reflect in any way the official policy or position of the Department of the Air Force, Department of Defense, or the United States Government.

D. PLAN OF DEVELOPMENT

In order to introduce this subject, first cited will be the results of some excellent references found in the literature on the capacity planning process accomplished in an MVS environment. Next, an overview of the methodology developed along with details about each of the following components: SELECT THE MEASUREMENT TOOL, SMF DATA SETS, HISTORICAL TAPE, RMF POST PROCESSOR, CONSTRUCTING A CAPACITY PLANNING DATABASE, GATHERING INPUT DATA, REMOVING OUTLIERS, MODELING CONSIDERATIONS, and REPORTING. Along with a components description, if it applies, specific results achieved during the study are cited and documented. Finally, some conclusions and recommendations formulated from the study, along with a few suggestions for future research, are presented.

II. REVIEW OF THE LITERATURE

A. DEFINITION OF CAPACITY PLANNING

Any introduction to capacity planning should first address the following fundamental question: what is capacity planning? This term, as used in the field of data processing, has many definitions. Among the many authors reviewed in the literature, one definition which is simple, clear, and concise stands out beyond the rest.

> Capacity planning is the means whereby one can achieve meaningful forward estimates of the resources needed, both hardware and software, relative to the demand expected to be imposed by the workload. (1: p. 41)

The selection of the above definition is by no means a criticism of the definitions presented below, but is only an identification of some of the diverse opinions the new capacity planner must consider.

> Capacity planning is a methodology developed for the management and control of the complex data processing environment. (2: p. 1)

> Capacity planning is a measured and structured view of the current and projected system environment. (3: p. 518)

> Capacity planning is the process of relating business requirements to data processing parameters and estimating the DP system that can satisfy those business requirements. (4: p. 5.1)

> Capacity planning is the process of continually monitoring a system and its workloads and recommending changes, if necessary, to ensure that the system is never out of capacity. (5: p. 586)

> Capacity planning is the process of understanding and predicting the performance of a production data processing installation in order to maintain sufficient processing capacity for that installation. (6: p. 204)

> Capacity planning is basically the following three-step procedure: (1) account for current usage, (2) forecast future usage, and (3) match host resource requirements to a future configuration. (7: p. 64)

Although these definitions and many others have presented differing views of capacity planning, they all tend to link their definitions to a single idea. Each is concerned with developing some kind of process whereby one can obtain accurate and controlled estimates of today's workloads in order to meet tomorrow's data processing needs and expectations.

B. METHODOLOGIES

In order to perform capacity planning, a method must be selected as a good starting point. Historically, a good starting point to gauge MVS system capacity is to use CPU utilization data. Therefore, the procedure which has become the base of many successful methodologies is a technique called USAGE (Understanding Your Application and Growth Environment).

In 1974, USAGE was developed in Canada, by Prem C. Agrawal and Edward C. Turgeon, and was based on the experiences of some forty large data processing installations. It was brought to the United States in 1976 for further testing, and the resulting program has been operating since January 1977. Although a simple methodology, it has been widely used throughout the computing industry for the past decade basically to understand current workloads and to forecast future workload requirements. (8)

In 1980, J. C. Cooper (8), an advisory support representative at the IBM Washington Systems Center, developed "A capacity planning methodology" (8) based on USAGE. His approach was one of the first published which was aimed at computer systems whose operating system was MVS. Since this study, many authors have extended the USAGE approach.

One of the first authors to extend the USAGE approach to include the Input/Output (I/O) subsystem was J. B. Major. (7) The I/O subsystem includes both the input/output path and

direct access storage device resources. His Start Input/Output (SIO) methodology emerged from the author's previous work that utilized queueing models to study configuration relationships. (7: p. 65) The fundamental theory put forward is that processor workload compares directly to I/O resource requests for a given workload. Workloads are correlated through a measure called relative I/O content. (9) Once given an existing SIO rate and relative I/O content, future capacity requirements can be forecasted based upon installation defined growth rates. This methodology has been extended by Remi Davalibi, an IBM Senior Systems Engineer, and is used by an automated capacity planning methodology called Capacity Planning for the 80's (CP80). (9)

CP80 is a capacity planning program available by contacting an IBM Marketing Representative or Systems Engineer. This methodology has the following highlights:

- Uses Proven Methodology (SIO by J.B. Major)
- Provides Measurement of Existing Capacity
- Projects Future Capacity Requirements Relative to Various IBM CPU's
- Projects DASD Growth Requirements
- Provides Resource Bottleneck Analysis
- Produces Customized Color Charts and Graphic Projections
- Applicable to MVS Environments (9)

In addition, another methodology based on the USAGE concepts was developed by Dr. LeeRoy Bronner. (10) His approach can be used as a first cut approximation for sizing

the host requirements of a computing system. (10: p. 25) Upon reviewing this work, a capacity planner should be able in a few days (i.e., one to two days) to access an estimate of the capacity needs in his MVS shop.

Dr. Bronner (2, 10, 11, 21) has published many other articles addressing capacity planning. For example, his article entitled "Overview of the capacity planning process for production data processing" (11) definitely discusses many of the fundamental concepts and ideas one needs to implement a capacity planning effort. In fact, this work has become the basis of the methodology developed in this thesis.

Another author whose publications have inspired this author personally is H. Pat Artis. (12) He has shared his ideas freely about methodologies for determining the capacity of a computer system. Specifically, his article "Capacity Planning for MVS Computer Systems" (12) probably comes the closest to providing management with essential information about the capacity of their existing systems.

One of the more complex capacity methodologies involving MVS is an IBM marketing aid informally called SCAPE (System Capacity and Performance Evaluation). It has been used as an aid for capacity planning in about 50 installations in the United States. In most instances, SCAPE has made a significant difference in determining the best configuration for future use, justifying the procurement of hardware, or pinpointing possible bottlenecks. (13)

Finally, when one discusses performance evaluation and capacity planning, there is one author who stands out in the field today, namely Dr. H. W. "Barry" Merrill. (14) His work is presented in a book of 867 pages which is divided into forty-two chapters of various computer performance evaluation topics. This book is both an outstanding teaching tool and an excellent reference manual to which every MVS shop should have immediate access.

Many methodologies can be found throughout the computer market place today which claim to perform lengthy data gathering and reduction efforts, model development, verification, and validation, and finally system analysis. However, having to select one of these methodologies for an installation depends on many factors including hardware, software, program products, computer staff, level of management support available, and the size of a capacity planning budget. Upon considering these factors and others, each installation will probably learn a valuable lesson which many other installations have faced or are going to face. There is no one specific way in which capacity planning should be implemented in an MVS environment, but a methodology is required.

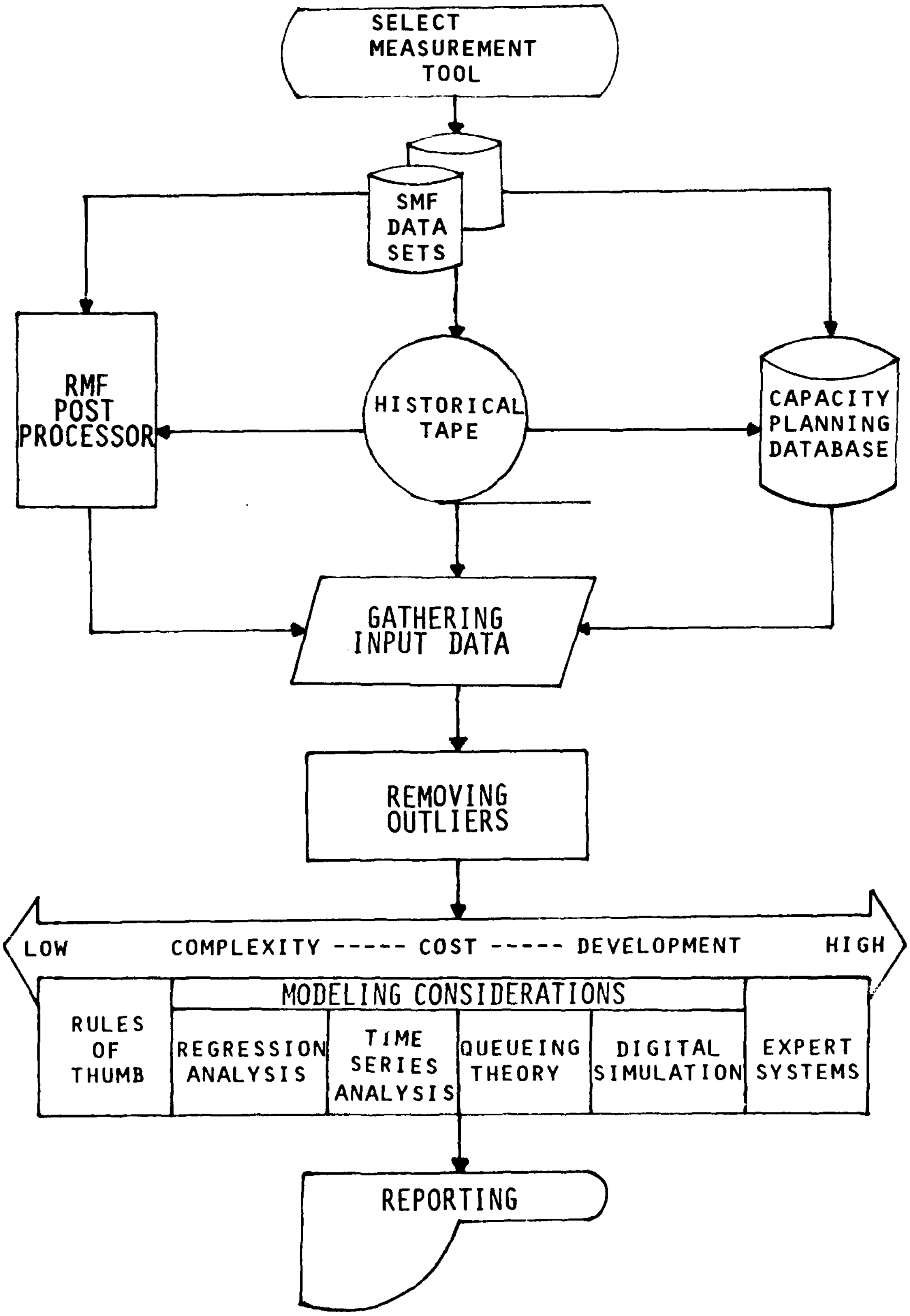

Figure 1. Flowchart of the methodology

III. METHODOLOGY DESCRIPTION AND RESULTS

A. OVERVIEW

Here is a new capacity planning methodology. Arranged in nine components, as shown in Figure 1, it supplies each MVS installation with the actual usage data in order to help set accurate user objectives and forecast for tomorrow's data processing needs. It is primarily directed toward an installation that has a stable configuration which is reasonably well tuned and will continue in that state for an adequate measurement period.

In clear, practical detail, the author begins by selecting a measurement tool. He presents the specific components which utilize the data produced by the measurement tool. Then he describes a wide range of modeling approaches available which not only provide aid to the capacity planner but are among the most important tools in use today. Although the methodology described here is not composed of any new computer performance evaluation ideas, it has adapted the scientific methods of exhaustive investigation and experimentation in order to fully utilize only the best available computer performance evaluation ideas.

B. SELECT THE MEASUREMENT TOOL

The starting point for developing this capacity planning methodology begins with the selection of a desirable

measurement tool. Before selecting a specific measurement tool (see Appendix A), several factors need to be considered. First, the measurement tool must be easy to use. Second, the measurement tool must have little or no impact itself on overall system performance. Third, the measurement tool must be able to collect accurate measurements about utilization of system resources. Finally, the measurement tool must be capable of providing information which can be used to identify all or portions of the hardware configuration which processed the computing workload. All factors considered, the best measurement tool available today for computer system capacity planning is the Resource Measurement Facility (RMF).

C. SMF DATA SETS

SMF (System Management Facilities) is a standard feature of OS/VS2 MVS that collects and records information about various areas of system wide activity. Each SMF record produced by an IBM program product is described in the IBM manual OS/VS2 MVS System Programming Library: System Management Facilities (SMF). (15) The SMF records of particular interest are the ones written by the Resource Measurement Facility (RMF). The SMF record types and the corresponding RMF measurement activities are listed in Appendix B.

D. HISTORICAL TAPE

The historical tape is built by selecting the RMF generated records from the SMF data sets using the SAS system. Other data set utilities can also be used with this methodology. The tapes built using the Job Control Language (JCL) and SAS software presented in Appendix C, resulted in each 6250 BPI (Bytes Per Inch) tape being able to hold six months of SMF records. Therefore, an installation can have a complete history of its yearly data processing environment on just two tapes! This is a very small price to pay for such vital information about the actual usage patterns occurring within a data processing environment.

E. RMF POST PROCESSOR

The post processor is a powerful piece of software which uses RMF generated SMF records to produce various kinds of reports. It can usually be found in load module format in the partitioned dataset SYS1.LINKLIB. The member name is ERBRMFPP.

The input to the post processor program comes in two forms: data input and control input. Data input consists of SMF records from either SMF DATA SETS or the HISTORICAL TAPE mentioned above and control input consists of control statements. The control statements describe the type of reporting one wants the post processor program to do. (16: p. 2-68)

Output generated by the post processor program consists of printed reports. These reports constitute the main source of information regarding hardware configuration and MVS resource utilization.

For further details and a more in-depth discussion about the RMF post processor and its reports, refer to OS/VS2 MVS Resource Measurement Facility (RMF) Reference and User's Guide. (16)

F. CONSTRUCTING A CAPACITY PLANNING DATABASE

The construction of a capacity planning database is usually dependent upon the installation. Although it is possible for any installation to develop its own database system, that is, to create its own methods and software, the complexity of such an endeavor and a lack of time and money usually prevent this decision. Therefore, the only legitimate alternative left for the new capacity planner is to purchase the appropriate materials that will facilitate the installation in accomplishing this most crucial task.

Thanks to innovations brought about by H. W. "Barry" Merrill as a pioneer in the computer performance field, an installation can purchase from SAS Institute his materials, entitled Merrill's Expanded Guide to Computer Performance Evaluation Using the SAS System (MXG). (14) The product MXG consists of three parts: the book, the MXG software, and the support subscription. His book, mentioned above, consists of 867 pages divided into forty-two chapters of various computer performance evaluation topics, including one chapter about building a performance database. In addition, the MXG software, consisting of more than 200 SAS programs, is readily available to help each installation construct an ongoing capacity planning database. Finally, the support subscription is the most valuable part of the investment because it provides maintenance, enhancements, and updates to the MXG software. Thus, computer professionals are able to devote all of their time and energies to an installation's capacity planning goals and efforts.

G. GATHERING INPUT DATA

Up to this point, three sources of information are readily available to determine and track ongoing utilization of resources. They are the reports produced by the RMF post processor, the historical tape, and the capacity planning database. With such data at hand, the capacity planner must now consider how best to use each source as a capacity planning tool. Experience has shown that much time, effort, and money can be saved by utilizing available reporting from the RMF post processor.

The following discussion about utilizing available reporting as a source of gathering input data for modeling endeavors is intended to identify both an installation's computing resources and how they are being used by users. This is done by extracting specific information from a number of RMF post processor reports using SAS. Since the programs developed by the author wi: soon be outdated because of unknown updates to RMF and utilize portions of MXG software, which is copyright protected, they are not included. However, once a set of programs is completed by an installation, this procedure can be repeated any time. This allows an installation to accurately obtain the correct information about its hardware configuration or MVS resource utilization levels.

This discussion begins by trying to obtain information about a hardware configuration. First of all, a diagram must be created which shows what computing resources an

installation owns. This diagram should include at least the CPU, channels, control units, direct access storage devices (DASD), tape drives, printers, and terminals, along with any other specific information such as a model, serial, or version number which could be used to further identify any individual piece of hardware.

In examining the diagram maintained at Offutt AFB, Nebraska, the author found on a number of occasions that the information was not entirely correct. This led the author to find an automated way to keep the information on the diagram as current as possible. Originally, the output produced from RMF post processor reports called the CPU Activity (see Appendix E) and the Direct Access Device Activity Report (see Appendix F) were used to track when configuration changes actually took place. In using the output of these reports as input to a SAS program, it was possible to identify the CPU by model number and serial number, along with the number of channels and various I/O devices that were currently in use. After several months, this process of keeping track of the hardware configuration turned out to be more accurate and reliable than the person who was manually maintaining the diagram. At this point, the author realized the same information could be obtained by writing SAS programs using a capacity planning database as the input source of information. These programs provided dependable results and were much easier to maintain because all changes were handled at the MXG database level.

The most difficult part of any capacity planning analysis is to report how the computing resources are being used by users. In the past, users themselves have predicted their resource usage with some degree of success. However, their results are usually highly subjective and frankly, of dubious value, primarily because users are often people who may not have a computing background. These users of software often relate to programs as tools to help them accomplish their jobs without any concern regarding what resources are being utilized.

Although it is true that users will continue to be an essential element to successful capacity planning, especially in providing estimates of anticipated future requirements, the single most important ingredient in identifying actual resource utilization within a computing environment must come from system accounting data as produced by RMF. Experience has shown that this data and the use of the RMF post processor enables one to utilize available reporting means to analyze current and past computing environments.

The available reporting of primary interest for capacity planning purposes are summary reports. Summary reports provide a high-level view of system activity and contain important information about how much work is really being accomplished. Therefore, each MVS installation is supplied with the actual usage data to help set accurate user objectives and forecast for tomorrow's data processing needs.

The information is located on a RMF post processor report called the RMF SUMMARY REPORT (see Appendix G). This report can be generated as a batch job (see Appendix D) and used as input to a SAS program. A brief discussion of this report and the data fields which were extracted follows.

RMF SUMMARY REPORT: This report consists of several data fields which provide a high-level view of various areas of system wide activity. However, only one data field can be recommended for use as an important measure of MVS system capacity. The data field is CPU BUSY. Each value reported in this field comes from the RMF type 70 record and covers the range from 00.0 to 100.0 percent. This measure of CPU utilization has been both validated and verified as being as accurate as any hardware monitor measures. (17: p. 591) With this data alone, the USAGE methodology as described previously can be implemented.

In addition to the data field mentioned above, in early 1985, the author extracted the data fields DASD RATE and TAPE RATE. These fields, along with the hardware configuration data discussed above, provided the necessary input to use for a study of existing capacity requirements. This study was conducted using the IBM automated capacity planning methodology known as CP80.

This opportunity to work with an IBM account team on a professional basis proved to be a most meaningful and rewarding personal experience. In fact, it was during this time of learning, exploring, investigating, and actually

doing a real study of one computer system workload that made this author realize this approach is worth communicating to others. During the course of this study, the author made the following personal observations. First, some of the CP80 color charts showed that this current hardware configuration was not sufficient. Having been a part of this organization for over three years, this result was predictable, but could never be substantiated until the CP80 results were analyzed. These results showed that this problem could be resolved by running this workload on a larger CPU with more real memory. Since this installation had two other larger systems with more real memory but each was processing a different workload. The solution to this problem appeared simple since the workloads on these systems never fully utilized the available resources, due to the fact that the self-interests of certain groups and how much money Congress allocated each year were governing the present situation and guiding future decisions. However, this was not entirely the fault of the decision makers. They were doing what they thought was best for the installation based on the information available, which was usually user input. So let this be a lesson to other installations, who find themselves without adequate resources to satisfy expanding demands because they fail to provide a way to meet management's need for information about overall performance of their installation.

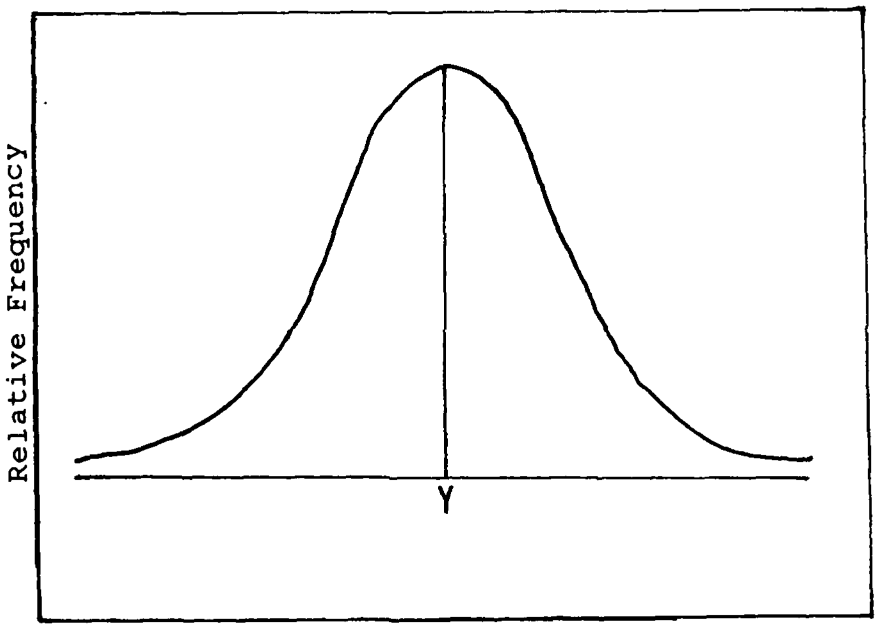

Figure 2. The normal distribution (18: p. 49)

H. REMOVING OUTLIERS

As might be expected, the next step after the available measurement data has been collected from these reports is to detect and remove outliers. Dr. Merrill states, "Outliers are those data observations that lie outside of the normal data". (14: p. 256) Usually these suspect points may arise for a number of reasons, most of which were caused by software and hardware failures or various operation interventions, such as holidays. The following represent diagnostic methods currently available.

One of the easiest ways of reducing the volume of measurement data involves plotting the data by using a software system like the Statistical Analysis System (SAS). (14: p. 256) Generally, by visual inspection, one should be able to determine if there are outliers that should be removed.

Another natural and convenient way of handling this problem is to apply a simple statistical approach. This approach consists of several steps based on the concepts of the Empirical Rule as given by Mendenhall.

> The Empirical Rule: Given a distribution of measurements that is approximately bell-shaped (see Figure 2), the interval
>
> 1. $\mu \pm \sigma$ will contain approximately 68 percent of the measurements.
> 2. $\mu \pm 2\sigma$ will contain approximately 95 percent of the measurements.
> 3. $\mu \pm 3\sigma$ will contain all or almost all of the measurements. (18, pp. 48-49)

The steps taken are as follows: First, using SAS, obtain a group of measurements such as the CPU BUSY data field from an RMF SUMMARY REPORT and plot them to insure they are approximently bell-shaped. In fact, one of the goodness-of-fit tests, like a Kolmogorov-Smirnov or Chi-square, could be used. (19, pp. 319-323) Then, use the SAS procedure SUMMARY on the measurements obtained above in order to compute various descriptive statistics. The statistics of primary interest are the mean and the standard deviation. Finally, remove all data points which are not within two standard deviations of the mean. In the case of the author's installation, this mathematically unsophisticated technique successfully identified all holidays and known software and hardware failures.

For those who have a strong statistical background, the treatment of this problem can be handled using regression analysis. With the aid of the SAS regression procedure, PROC REG, various statistics can be utilized to solve this problem. In fact, the book entitled Classical and Modern Regression with Applications by Raymond H. Myers (20) contains comprehensive coverage of regression using SAS. A more complete discussion of regression analysis and other modeling approaches follows.

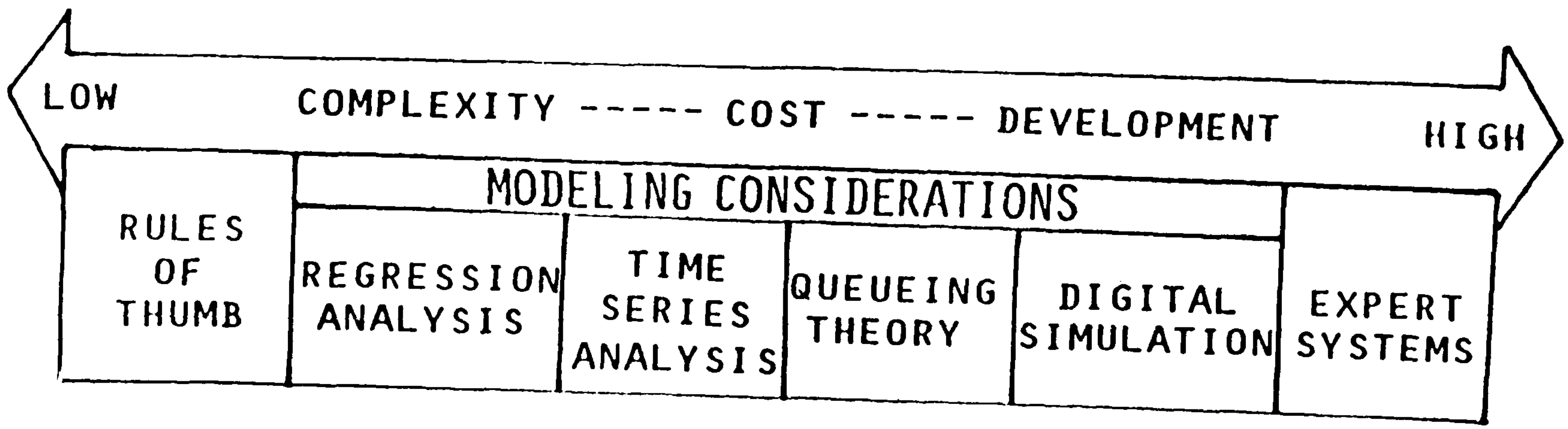

Figure 3. Spectrum of modeling approaches

I. MODELING CONSIDERATIONS

The actual process of capacity planning given the appropriate data, turns out to become a problem in modeling. Fortunately, there are a wide range of modeling approaches available which not only provide aid to the capacity planner but are among the most important tools in use today (see Figure 3). This figure was developed in conscious imitation of the style adopted by L. Bronner. (21)

Before discussing each approach, the following question needs to be answered: what is a computer system model? Basically, it is anything which serves as a representation of an actual computer system. Possibly, with this representation, capacity planners will increase their knowledge and understanding of their present computing situation in order to answer any questions about changes or additions one would like to make to accomodate future growth requirements.

First of all, rules of thumb are the simplest and by far the least expensive. This is largely due to the fact that rules of thumb have evolved over the years from the experiences of computer professionals who focus on the issues of performance, planning, and management of computer systems. Dr. Arnold O. Allen (22) sites the following example of rules of thumb for MVS computer systems:

- Generally, channel utilization in DASD should not exceed 35 percent for on-line applications or 40 percent for batch applications.
- Individual DASD device utilizations should not exceed 35 percent.
- The average arm seek length on a DASD device should not exceed 50 cylinders. (22: p. 325)

All the rules of thumb above are useful guidelines for identification of potential problems which may occur on a day-to-day basis. However, most of them are really useless in forecasting additions necessary to accomodate future growth requirements.

Secondly, regression analysis has received much attention in the past 25 years and continues to grow in popularity. This topic is known as the process of constructing and analyzing functional relationships between a response, the dependent variable Y, and important factors, the independent variables $X_1, X_2, \ldots, X_K$ that affect the response. The relationship which "best", in some sense, represents the response as a function of the independent variable is selected for use in predicting future responses for fixed values of the independent variables. (19: p. 326) In a computer system model, regression analysis can be used to to estimate future utilization of components such as central processing units, channels, direct access storage devices, and tape drives. Unfortunately, the performance of components of a computer system is usually not a linear relationship of the independent variables that might affect the dependent variable. Therefore, regression analysis can be used to predict performances only at very low levels of utilization.

Quite often, the only data available for use in constructing a forecast take the form of a time series. (23: p. 232) According to C. Chatfield, "A time series is nothing more than a collection of observations made sequentially in time". (24: p. 1) Since RMF measurement data is collected as a time series, this is the most natural and least expensive approach available to capacity planners for forecasting. Two basic approaches to modeling a time series for forecasting include: time trend and time series.

A time trend approach captures long-term behavior by fitting equations as functions of time. Generally trend functions are either polynomials or exponentials. When the data has a seasonal pattern, the trend forecast can also be adjusted for seasonality. (25: p. 302)

A time series approach models short-term fluctuations using such methods as the autoregressive model (26). Good automated approaches can combine the two approaches and have enough flexibility to model many different behaviors across time. (25: p. 302)

For examples and more information, refer to the tutorial presented at last year's Computer Measurement Group (CMG) Conference by Bruce A. Ingraham. (27)

The next modeling approach to be considered is not only one of today's most popular techniques of analytic modeling, but it is gaining widespread use by many computer professionals. This approach is called queueing theory. Queueing models are ideal for modeling computer systems

because requests in a computing environment usually find the CPU busy, a disk drive busy, or some other resource they must wait for. Therefore, a common problem faced by a capacity planner is how to balance the cost associated with waiting versus the cost associated with the prevention of waiting in order to utilize all resources in a computing facility efficiently. By analyzing a computing facility as a group of queueing systems, a capacity planner can find solutions to this problem.

Years ago, when analytical (queueing) modeling was not generally available for practical use and the user environment was simpler, benchmarking was an attractive alternative for a moderately sized installation to evaluate other configuration alternatives. (28: p. 390) However, with today's computing environments constantly increasing in complexity, this approach is only practical if done in a vendor environment. This is mainly due to the fact that many installations simply cannot afford to go to a site which has a system similar to a proposed alternative. In most instances, only installations with a great deal of understanding of their data processing operations can adequately use the results of benchmarking as their only capacity planning tool. (11: p. 21)

According to Dr. Arnold O. Allen, "Simulation has been a popular computer modeling technique for years". (22: p. 325) It is an approach which provides a means of testing, evaluating, and weighing alternatives of a proposed computer system without affecting the real computer system.

Unfortunately, this technique is costly, time consuming, and requires a skilled (and usually large) staff to build, validate, run, interpret, and verify a simulation model. (22: p. 325)

An expert system for computer performance modeling involves the new generation of qualitative tools available to capacity planners. Expert systems are also called Knowledge-Based Systems, since their performance depends on combining principles of Artificial Intelligence (AI) programming with specific domain knowledge. (29: p. 227) With this technology, capacity planners will not only be able to automate the building of a computer system model, which has turned out to be a major effort in many computing installations, but they will finally have available the knowledge of a specific area of expertise which can be used to solve problems by others who may not be experts in the specific area in which a problem has occurred.

In summary, all the modeling approaches allow capacity planners to draw quick and accurate conclusions about a computer system's behavior. However, each approach is only useful for modeling computer systems given the appropriate data is available.

J. REPORTING

Reporting about capacity planning is a crucial endeavor which should provide decision makers with a high-level overview of how well the installation is operating. Reports should include data about the patterns of usage and relative consumption of resources regarding both prime and nonprime shifts. They should also include data to support long range planning and forecasting.

This can be executed in a variety of ways depending upon the expense of the reports generated, the type of reports, and the level of sophistication an installation wishes to undertake. Since most reports will be tailored to an organization, the capacity planner should strive for simplicity in design. Using graphs and charts ("A picture is worth a thousand words") instead of cluttering numeric values will add credibility to recommendations. The bottom line toward surviving in today's rapidly changing competitive business world boils down to being able to report changes promptly so that management has ample time to accurately access them.

IV. CONCLUSIONS AND RECOMMENDATIONS

The demand for a capacity planning methodology has long been a vital concern of many MVS installations. In dealing with this problem, this thesis has shown that the methodology discussed herein is a very suitable beginning for implementing a capacity planning effort in an MVS environment. Included is a comprehensive review of current literature which has revealed no other methodologies which combine all of its features. In addition, this methodology combines the results of these references and the most attractive ideas available in order to serve as a process whereby one can obtain accurate and controlled estimates of today's workloads in order to meet tomorrow's data processing needs and expectations.

The highlights of this methodology, as shown in Figure 1, consists of the following nine components: SELECT THE MEASUREMENT TOOL, SMF DATA SETS, HISTORICAL TAPE, RMF POST PROCESSOR, CONSTRUCTING A CAPACITY PLANNING DATABASE, GATHERING INPUT DATA, REMOVING OUTLIERS, MODELING CONSIDERATIONS, and REPORTING.

This methodology, as developed and evaluated, is intended to enhance the capabilities of MVS installations in identifying the point in time when the arrival rate of the work will exceed the capacity of the available resources to process it within the desired service objectives. It has

achieved this by overcoming the major obstacles of not handling too much raw data and the avoidance of using disjoint measurement tools. This was accomplished through selection of only one measurement tool known as the Resource Measurement Facility (RMF).

The methodology also was designed to aid new capacity planners in selecting an appropriate modeling approach. For proper selection and use of an approach, the following recommendations are given:

1. Avoid using rules of thumb because most of them are really useless in forecasting additions necessary to accomodate future growth requirements.

2. Use regression analysis only for detecting outliers and other influential data points of interest.

3. Use time series analysis as a first cut approximation in determining how much work is really being accomplished.

4. Using RMF data in conjunction with the IBM automated capacity planning methodology known as CP80 indirectly utilizes queueing theory. Once completing a study, the procedure can be repeated on a regular basis to track actual usage as an integral component of installation management. Best of all, this methodology is easy to use and requires minimal resource to complete. (9)

5. Use simulation, if known distributions of CPU utilization and I/O utilization are readily available.

6. Strive to automate the building of a computer system model by combining the principles of AI programming with specific domain knowledge.

In closing, it may be stated that the fundamental concepts of this methodology are open to no known legal objections, and that the advantages gained from this experience are sufficient to far outweigh any shortcomings it may contain.

V. SUGGESTIONS FOR FURTHER STUDY

As this methodology was being developed, a number of new computer performance evaluation ideas concerning MVS environments were found. They include the following:

1. A forecasting technique such as Box-Jenkins should be applied to at least a year or more of RMF measurement data, especially values concerning CPU utilization, in order to build a good explanatory model which can be used for future predictions. Studies should utilize SAS procedures PROC ARIMA and PROC FORECAST.

2. A regression analysis study using RMF measurement data could be conducted without concern of developing a predictive model, but to use the statistics produced by the SAS procedure PROC REG to detect outliers and other influential points of interest.

3. The SAS procedure PROC FREQ could be used for scanning RMF measurement data to determine if any known distributions exist for such values as CPU utilization.

4. Hardware capacity of an MVS computer system can be expressed in terms known as service units. Service units are computed as a combination of three basic system resources: CPU time used, I/O activity (EXCP counts for data sets associated with the address space), and real storage frames occupied. (30: p. 7-4) Using RMF measurement data, one can identify and compute how many service units per hour a system can produce

and compare this value against the measured service units written to SMF records. For a good starting point, refer to chapter twenty-six in Merrill's book. (14: pp. 249-272)

5. Dramatic advances in the field of Artificial Intelligence (AI) have made automation of many previous labor intensive tasks practical, cost effective, and reliable. Therefore, implementing a capacity planning methodology based on an AI approach using RMF measurement data as input would surely become a valuable tool to the entire data processing profession.

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VITA

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While serving as a electronic computer repairman at Keesler AFB, Mississippi, he also earned credits toward his Associate in Applied Science degree in Electronic Computer Systems Technology, which he was awarded by the Community College of the Air Force in October 1979.

In June, 1979 he enrolled at Oklahoma State University in Stillwater, Oklahoma, under the United States Air Force's Airman Education Commissioning Program, and received a Bachelor of Science degree in Computing and Information Sciences in May of 1981. On August 28, 1981 he was commissioned a second lieutenant in the United States Air Force.

Upon commissioning, he was assigned to Offutt AFB, Nebraska as a systems programmer before enrolling in the Graduate School of the University of Missouri-Rolla in June of 1985 under a program sponsored by the Air Force Institute of Technology. He currently holds the rank of captain with over 13 years of active duty military service.

APPENDIX A
Program Products

Vendor	Program Product
Boole & Babbage	Control/SMF
BGS	BEST/1
BGS	CAPTURE/MVS
Candle Corporation	Omegamon
Candle Corporation	DEXAN
Duquesne	Quantitative Computer Management (QCM)
IBM	System Management Facility (SMF)
IBM	General Trace Facility (GTF)
IBM	Capacity Planning Extended (CPX)
IBM	CP80
IBM	MVS Resource Management Facility (RMF)
Morino Associates Inc.	MVS Integrated Control System (MICS)
Morino Associates Inc.	TSO/MON
SAS Institute Inc.	Statistical Analysis System (SAS)

APPENDIX B
SMF Records

Each SMF record produced by RMF is described in OS/VS2 MVS System Programming Library: System Management Facilities (SMF). The record types and the corresponding RMF measurement activities are:

- Record Type 70 - CPU activity
- Record Type 71 - paging activity
- Record Type 72 - workload activity
- Record Type 73 - channel activity
- Record Type 74 - device activity
- Record Type 75 - page/swap data set activity
- Record Type 76 - trace activity
- Record Type 77 - enqueue activity
- Record Type 79 - Monitor II activity

Record type 79 has the following sub-types; these sub-types are:

- Sub-type 1 - address space state data
- Sub-type 2 - address space resource data
- Sub-type 3 - real storage/processor/SRM
- Sub-type 4 - paging
- Sub-type 5 - address space SRM data
- Sub-type 6 - reserve data
- Sub-type 7 - enqueue contention data
- Sub-type 8 - transaction activity data
- Sub-type 9 - device activity
- Sub-type 10 - domain activity
- Sub-type 11 - paging activity
- Sub-type 12 - channel activity (16: p. 8-1)

APPENDIX C
Constructing an Historical Tape

```
//        JOB card
//*
//* Read this very carefully or the historical tape built
//* by this job stream will be useless !!!
//*
//* In order to use this job do the following:
//*
//* 1.  Point the DD card SMF to the weekly SMF tapes which
//*     contain the monthly data one wishes to process.
//* 2.  Change the DD card TAPE so it has the dataset name
//*     of the data one is processing, the correct file
//*     number in the LABEL parmeter, and the correct
//*     volume serial number !!!  (i.e. January would be
//*     file 1 on the first historical tape and July
//*     file 1 on the second historical tape)
//* 3.  Change the record located in the SAS source code
//*     which follows the SAS CARDS; statement to the month
//*     one is to process. Note it is the card below with
//*     XXX in it.
//*
//SAS      EXEC PGM=SAS load module
//SMF      DD   dataset contains SMF records (tape or DASD)
//TEMPDASD DD   temporary dataset contains RMF records for
                use in other job steps
//TAPE     DD   tape dataset contains RMF records
//SYSIN    DD   *
* SAS PROGRAM;
DATA MONTH (KEEP=MONTH);
*;
* THIS DATA STEP READS THE MONTH ONE WISHES TO PROCESS;
*;
FORMAT INMONTH CHAR.;
INPUT INMONTH;
IF          INMONTH = 'JAN' THEN MONTH=1;
   ELSE IF INMONTH = 'FEB' THEN MONTH=2;
   ELSE IF INMONTH = 'MAR' THEN MONTH=3;
   ELSE IF INMONTH = 'APR' THEN MONTH=4;
   ELSE IF INMONTH = 'MAY' THEN MONTH=5;
   ELSE IF INMONTH = 'JUN' THEN MONTH=6;
   ELSE IF INMONTH = 'JUL' THEN MONTH=7;
   ELSE IF INMONTH = 'AUG' THEN MONTH=8;
   ELSE IF INMONTH = 'SEP' THEN MONTH=9;
   ELSE IF INMONTH = 'OCT' THEN MONTH=10;
   ELSE IF INMONTH = 'NOV' THEN MONTH=11;
   ELSE IF INMONTH = 'DEC' THEN MONTH=12;
   ELSE PUT
   'INVALID INPUT - MONTH MUST BE THREE CHARACTERS';
   CARDS;
   xxx
```

```
    ;
DATA MONTHLY;
*;
* THIS DATA STEP BUILDS A TEMPORARY FILE ON DASD;
* AND BUILDS A FILE ON THE HISTORICAL TAPE;
*;
IF N = 1
   THEN DO;
           SET MONTH;
           RETAIN MONTH;
        END;
INFILE SMF STOPOVER END=EOF LENGTH=SMFLEN;
INPUT 2 ID PIB1. ;
IF ID >= 70 AND ID <= 79
   THEN DO;
           INPUT 7 JULIAN PD4.;
           FORMAT DATE DATE7.;
           DATE = DATEJUL(JULIAN);
           SMFMONTH = MONTH(DATE);
           IF MONTH = SMFMONTH
              THEN DO;
                      FILE TEMPDASD;
                      PUT _INFILE_;
                      FILE TAPE;
                      PUT _INFILE_;
                   END;
              ELSE DELETE;
        END;
   ELSE DELETE;
```

APPENDIX D
RMF Post Processor Example

```
//*
//* RMF SUMMARY REPORT JCL AND CONTROL STATEMENTS
//*
//RMFSUMRY JOB   accounting information
//RMFPOSTP EXEC  PGM=ERBRMFPP
//MFPINPUT DD    data set contains RMF generated SMF records
//*              from SMF datasets or historical tape
//SYSIN    DD       *
  SUMMARY(INT,TOT)
/*
```

APPENDIX E
CPU Activity Report (16: p. 5-17)

C P U   A C T I V I T Y

OS/VS2 RELEASE 03.8 | SYSTEM ID C303 RPT VERSION 08 | DATE 7/15/81 TIME 06.44.40 | INTERVAL 15.19.456 CYCLE 1.000 SECONDS

SU'S = 0,1,3,4,5,6,7,8,9,10,11,13,14,15,16,17,20,24,25,27,29,30,32,33,34,35,40,41,43,47,48,49,50,51,52,53,54,55,57,58,
60,61,62,63,64,65,68,74,78,95,96,99

CPU MODEL 3033

CPU NUMBER	WAIT TIME HH.MM.SS.TTT	WAIT TIME PERCENTAGE	CPU SERIAL NUMBER
1	00.13.12.489	86.19	020051
AVERAGE		86.19	

SYSTEM ADDRESS SPACE ANALYSIS   SAMPLES = 919

TYPE	NUMBER OF ASIDS MIN	MAX	AVG	DISTRIBUTION OF QUEUE LENGTHS (%) 0	1	2	3	4	5	6	7-8	9-10	11-12	13-14	14+
IN READY	1	8	1.1	0.0	87.8	11.3	0.5	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0
				0	1-2	3-4	5-6	7-8	9-10	11-15	16-20	21-25	26-30	31-35	35+
IN	6	15	6.9	0.0	0.0	0.0	17.3	81.3	0.2	1.0	0.0	0.0	0.0	0.0	0.0
OUT READY	0	7	0.0	99.7	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OUT WAIT	3	18	6.3	0.0	0.0	79.8	1.5	0.0	0.0	1.0	17.5	0.0	0.0	0.0	0.0
LOGICAL OUT RDY	0	0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LOGICAL OUT WAIT	0	1	0.1	88.1	11.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BATCH	0	2	0.9	12.1	87.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
STC	10	26	12.5	0.0	0.0	0.0	0.0	0.0	77.2	3.9	0.1	18.4	0.2	0.0	0.0
TSO	0	0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX F

Direct Access Device Activity Report (16: p. 5-28)

D I R E C T   A C C E S S   D E V I C E   A C T I V I T Y

PAGE 4

OS/VS2
RELEASE 03.8

SYSTEM ID C303
RPT VERSION 08

DATE 7/15/81
TIME 09.00.00

INTERVAL 60.00.199
CYCLE 1.000 SECONDS

TOTAL SAMPLES = 3,600

DEV ADR	VOLUME SERIAL	LOG CHN	DEVICE ACTIVITY COUNT	DEVICE ACTIVITY RATE	AVG SERV TIME	PERCENT QUEUE LENGTH DISTRIBUTION 0	1	2	3+	AVG Q LNGTH	--%REQ DEFER-- DISTRIBUTION DEV BUSY	PATH BUSY	% DEV BUSY	% CU DELAY	% REQ CU DELAY	% RESV DELAY	% REQ RESV DELAY	% DEV RESV	AVG DS OPEN	% ALLOC	% MT PEND
428	TSO428	7	14,150	3.930	0.043	95.8	3.8	0.4	0.0	0.05	76.47	23.53	17.25	0.83	4.54	0.0	0.0	18.4	12.5	100.0	0.0
450	IP0004	7	49,305	13.695	0.045	56.0	13.2	8.9	21.9	1.46	98.26	1.74	61.97	0.78	7.86	0.5	0.9	0.0	6.3	100.0	0.0
451	D24PAK	7	6,916	1.921	0.040	99.1	0.9	0.0	0.0	0.01	64.71	35.29	7.83	0.22	14.04	0.0	0.0	3.7	2.2	100.0	0.0
452	HOODL5	7	3	0.001	0.030	100.0	0.0	0.0	0.0	0.00	0.00	100.00	0.00	0.03	33.33	0.0	0.0	0.0	0.0	0.0	0.0
453	IPCS01	7	667	0.185	0.0[illegible]7	99.9	0.1	0.0	0.0	0.00	0.00	100.00	0.75	0.06	19.79	0.0	0.0	0.0	0.1	7.2	0.0
454	PAGE06	7	12,331	3.425	0.126	99.3	0.7	0.0	0.0	0.01	0.00	100.00	43.22	0.58	11.05	0.0	0.0	0.0	0.0	100.0	0.0
455	IPCS02	7	139	0.039	0.025	100.0	0.0	0.0	0.0	0.00	0.00	100.00	0.19	0.03	21.58	0.0	0.0	0.0	0.0	0.0	0.0
456	TSOPAK	7	0	0.000	0.000	100.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0
457	ZM497	7	418	0.116	0.025	99.9	0.1	0.0	0.0	0.00	0.00	100.00	0.33	0.06	16.51	0.0	0.0	0.0	0.8	74.6	0.0
460	ZZ04[illegible]	7	920	0.256	0.031	99.8	0.2	0.0	0.0	0.00	25.00	75.00	0.89	0.17	5.43	0.0	0.0	0.0	3.6	100.0	0.0
461	POK022	7	1,145	0.318	0.081	99.5	0.4	0.0	0.0	0.01	16.67	83.33	2.61	0.36	6.81	0.0	0.0	0.0	0.6	100.0	0.0
462	POK066	7	0	0.000	0.000	100.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0
463	POK148	7	0	0.000	0.000	100.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0
464	POK080	7	3,915	1.087	0.074	99.7	0.3	0.0	0.0	0.00	90.91	9.09	8.14	0.03	2.25	0.0	0.0	0.0	1.1	100.0	0.0
466	POK032	7	0	0.000	0.000	100.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0
467	POK083	7	15,319	4.255	0.043	95.0	3.8	0.8	0.4	0.07	90.57	9.43	18.50	0.44	0.94	0.0	0.0	0.0	2.2	100.0	0.0
531	LAVAN1	9	0	0.000	0.000	100.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0
532	ZB196	9	0	0.000	0.000	100.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0
533	ZB001	9	0	0.000	0.000	100.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0
534	SMPVOL	9	0	0.000	0.000	100.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0
928	SMAUG3	13	16,658	4.627	0.019	97.7	1.8	0.3	0.2	0.03	65.45	34.55	8.83	0.53	3.21	0.2	1.1	0.0	0.0	100.0	0.0
929	SMAUG4	13	15,927	4.424	0.020	97.3	2.0	0.4	0.3	0.04	73.33	26.67	9.08	0.53	3.13	0.2	1.7	0.0	0.0	100.0	0.0
92A	TSO92A	13	11,660	3.239	0.028	98.3	1.6	0.2	0.0	0.02	94.37	5.63	9.36	0.06	3.38	0.0	0.2	4.1	26.6	100.0	0.0
92B	TSO92B	13	7,361	2.045	0.023	99.4	0.6	0.0	0.0	0.01	45.45	54.55	4.83	0.22	2.85	0.0	0.0	2.6	10.7	100.0	0.0
950	IPURES	13	2,709	0.752	0.029	99.5	0.5	0.0	0.0	0.01	15.79	84.21	2.25	0.42	18.24	0.0	0.0	0.0	2.0	100.0	0.0
951	PAGE02	13	11,766	3.268	0.134	97.6	2.4	0.0	0.0	0.02	0.00	100.00	44.08	2.28	21.29	0.0	0.0	0.0	0.0	100.0	0.0
952	IPOL01	13	24,724	6.867	0.041	85.9	8.4	3.3	2.4	0.24	84.56	15.44	28.61	2.69	21.36	0.0	0.0	0.0	88.0	99.4	0.0
953	ZM970	13	NOW ONLINE																		
954	TSO190	13	94	0.026	0.038	100.0	0.0	0.0	0.0	0.00	0.00	0.00	0.17	0.00	29.79	0.0	0.0	0.0	0.1	51.4	0.0
955	CLRV12	13	52,966	14.712	0.047	45.9	14.7	12.5	26.8	1.61	98.74	1.26	69.56	1.08	16.99	0.0	0.0	0.0	43.1	100.0	0.0
956	PSGV03	13	235	0.065	0.030	99.9	0.1	0.0	0.0	0.00	0.00	100.00	0.25	0.08	20.85	0.0	0.0	0.0	0.0	13.8	0.0
957	SIPUNI	13	121	0.034	0.029	100.0	0.0	0.0	0.0	0.00	0.00	0.00	0.17	0.00	18.18	0.0	0.0	0.0	0.0	1.0	0.0
990	POK050	13	0	0.000	0.000	100.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX G
RMF Summary Report (16: p. 7-6)

R M F   S U M M A R Y   R E P O R T

OS/VS2
RELEASE 03.8

SYSTEM ID C303
RPT VERSION 08

START 07/15/81-06.44.40
END 07/15/81-12.00.00

INTERVAL 00.46.16
CYCLE 1.000 SECONDS

PAGE 001

NUMBER OF INTERVALS 8

TOTAL LENGTH OF INTERVALS 06.10.15

DATE MM/DD	TIME HH.MM.SS	INT MM.SS	CPU1 BUSY	BLMX1 RATE	DASD RATE	TAPE RATE	JOB MAX	JOB AVE	TSO MAX	TSO AVE	STC MAX	STC AVE	SWAP RATE	DEMAND PAGING	SERVICE RATE	TRANS RATE
7/15	06.44.40	15.19	13.8	43.4	43.2	0.0	2	1	0	0	26	13	0.03	1.06	1010	0.026
7/15	07.00.00	12.55	1.3	1.2	1.2	0.0	0	0	0	0	11	11	0.00	0.08	26	0.001
7/15	07.17.56	42.03	21.7	95.2	54.2	0.0	6	1	44	13	28	26	0.13	2.75	1006	0.714
7/15	08.00.00	60.00	85.4	149.8	121.2	0.0	11	7	114	75	28	22	0.59	14.84	2749	1.506
7/15	09.00.00	60.00	92.5	300.8	251.3	2.0	13	12	155	135	21	17	2.78	51.38	3828	3.978
7/15	10.00.00	59.59	87.7	279.8	235.6	4.6	13	12	165	159	20	16	3.46	52.32	3494	3.932
7/15	11.00.00	59.59	90.9	283.9	244.3	1.2	17	12	163	145	22	16	2.81	48.64	3859	3.804
7/15	12.00.00	60.00	98.3	250.4	208.5	1.0	18	16	131	120	20	17	0.80	30.32	4524	2.902
TOTAL/AVERAGE			76.6	217.6	179.9	1.4	18	10	165	105	28	18	1.71	32.45	3148	2.695